WRL reference	M05 D01
Module	M05 Natural Resource Use and Sustainability
Data set	D01 Identifying overfishing on Indonesian coral reefs

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Calculating an unpaired (independent) t-test by hand:

This document will give a short and simple explanation on how to take the raw data from Indonesian coral reef fisheries included in this data set, and to calculate the appropriate t-test results without relying on software (although a calculator might help)!

The instructions document has already discussed the fact that a t-test is the most suitable statistical test to compare the means of two data sets like the ones we have here (2005 and 2011). If individual values from both sets could be logically 'paired' (e.g. we measured the same fish in 2005 and 2011 and want to see if it has grown), we would use a paired t-test. However, we cannot do this, and so we need to use an unpaired (independent) t-test instead.

To calculate the *t*-value for an unpaired t-test, you will need to following values from each data set:

1. The mean of each data set
2. The standard deviation of each data set
3. The number of replicates (samples) included in each data set (this value is known as *n*)
4. The degrees of freedom for your test, which for an unpaired t-test is calculated using the following formula:
   $(n_1 + n_2) - 2$ (n is the number of replicates and the number refers to each data set)

You should have already calculated the mean of each data set in the Excel table provided, and if not you can find them in "M05 D01 CALCULATED". You will also see that there are 12 replicates in each data set (we surveyed 12 fish fence catches each year), meaning our *n* value is 12. This only leaves standard deviation to calculate. You can do this in Excel by using the same standard deviation formula (e.g. for the 2005 CPUE data set this would be **=STDEV(B3:B14)**).

Now you will have everything you need to calculate a *t*-value. The formula for this is as follows:

$$t = \frac{\bar{x}_1 - \bar{x}_2}{\sqrt{(s_1^2 / n_1 + s_2^2 / n_2)}}$$

Where:
x_1 = the mean of data set 1 (e.g. 2005 CPUE)
x_2 = the mean of data set 2 (e.g. 2011 CPUE)
s_1 = the standard deviation of data set 1
n_1 = the number of replicates in data set 1
s_2 = the standard deviation of data set 2
n_2 = the number of replicates in data set 2

This will give you your *t*-value, which means the hard part is over! The final step is to use your *t*-value with a reference table to find the probability that there is no difference between your data sets, and therefore be able to say with confidence that there is, or is no, a significant difference. The appropriate reference table for this test is below. You need to use a 2 tail test, and then find the column in with 0.05 in that row (0.05 means you are testing at a 95% confidence limit, as 1 – 0.05 = 0.95, and this is the standard level of confidence used by scientists). If you wanted to be extra confident, you could use a column with an even smaller number in it (e.g. the 0.001 column tests at the 99.9% confidence level). You then need to find the correct row for your degrees of freedom (df, calculated earlier), and note down the number where the correct column and row for your test meet.

If this number is smaller than your calculated t-test, that means you can confidently say that there is a statistical difference between your two data sets. If this number is larger than yours, you can say there is no statistical difference (at the 95% confidence level at least).

α (1 tail)	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
α (2 tail)	0.1	0.05	0.02	0.01	0.005	0.002	0.001
df							
1	6.3138	12.7065	31.8193	63.6551	127.3447	318.4930	636.0450
2	2.9200	4.3026	6.9646	9.9247	14.0887	22.3276	31.5989
3	2.3534	3.1824	4.5407	5.8408	7.4534	10.2145	12.9242
4	2.1319	2.7764	3.7470	4.6041	5.5976	7.1732	8.6103
5	2.0150	2.5706	3.3650	4.0322	4.7734	5.8934	6.8688
6	1.9432	2.4469	3.1426	3.7074	4.3168	5.2076	5.9589
7	1.8946	2.3646	2.9980	3.4995	4.0294	4.7852	5.4079
8	1.8595	2.3060	2.8965	3.3554	3.8325	4.5008	5.0414
9	1.8331	2.2621	2.8214	3.2498	3.6896	4.2969	4.7809
10	1.8124	2.2282	2.7638	3.1693	3.5814	4.1437	4.5869
11	1.7959	2.2010	2.7181	3.1058	3.4966	4.0247	4.4369
12	1.7823	2.1788	2.6810	3.0545	3.4284	3.9296	4.3178
13	1.7709	2.1604	2.6503	3.0123	3.3725	3.8520	4.2208
14	1.7613	2.1448	2.6245	2.9768	3.3257	3.7874	4.1404
15	1.7530	2.1314	2.6025	2.9467	3.2860	3.7328	4.0728
16	1.7459	2.1199	2.5835	2.9208	3.2520	3.6861	4.0150
17	1.7396	2.1098	2.5669	2.8983	3.2224	3.6458	3.9651
18	1.7341	2.1009	2.5524	2.8784	3.1966	3.6105	3.9216
19	1.7291	2.0930	2.5395	2.8609	3.1737	3.5794	3.8834
20	1.7247	2.0860	2.5280	2.8454	3.1534	3.5518	3.8495
21	1.7207	2.0796	2.5176	2.8314	3.1352	3.5272	3.8193
22	1.7172	2.0739	2.5083	2.8188	3.1188	3.5050	3.7921
23	1.7139	2.0686	2.4998	2.8073	3.1040	3.4850	3.7676
24	1.7109	2.0639	2.4922	2.7970	3.0905	3.4668	3.7454